FACTSHEET

The Precipitation and All-weather Temperature and Humidity mission

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

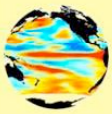
PATH - The Science

NRC Earth "Decadal Study":

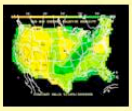
The 15 NASA missions:

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions	LEO, SSO	Multifrequency laser	$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M
Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	$650 M

Precipitation and All-weather Temperature and Humidity (PATH)
Launch: 2016-2020
Mission Size: Medium



Sea surface temperature



Temperature and humidity profiles

Constraints on models for boundary layer, cloud, and precipitation processes

More accurate, longer-term weather forecasts

Improved storm track and intensification prediction and evacuation planning

Determination of geographic distribution and magnitude of storm surge and rain accumulation

PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST[a]	GEO	MW array spectrometer	$450 M

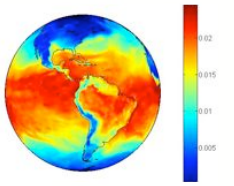
From "Earth Science and Applications from Space - National Imperatives for the Next Decade and Beyond"; © 2007 National Academies of Science

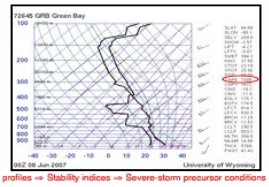
PATH Science Highlights:

Temperature and humidity profiles

Current capabilities:
- Poorly observed
  - In-situ: Few, fixed locations (raobs)
  - LEO satellites: Sampled 1–3x/day
  - GEO satellites: IR only ⇒ clear only
- Poorly predicted
  - Models deficient in severe conditions

PATH capabilities
- Clear *and* cloudy conditions
  - Observe IN storms (except heavy precipitation)
- Every 15–30 minutes everywhere
  - Observe storms develop



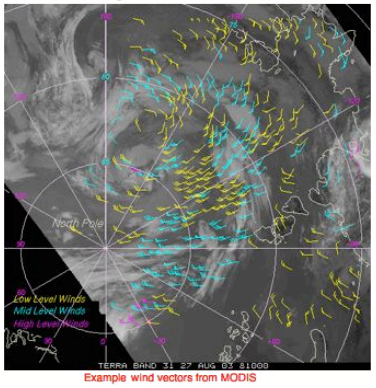


Sounding profiles ⇒ Stability indices ⇒ Severe-storm precursor conditions

Tropospheric wind vector profiles

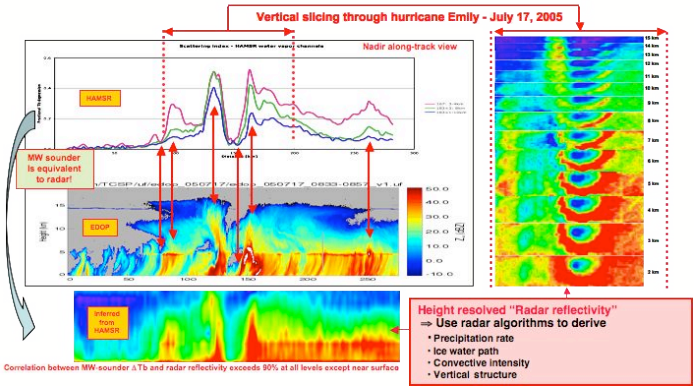
Current capabilities
- LEO satellites: MODIS
  - Polar regions only
  - Limited-accuracy water vapor profiles
- GEO satellites: IR sounder
  - Poor sampling: clear only
  - Uncertain height assignment
- GEO satellites: IR/Vis imager
  - Cloud tracking: cloud tops only

PATH capabilities
- Clear *and* cloudy
  - Including below clouds
- Continuous: no time gaps
- Applicable algorithms available
  - UW (Velden et al.)



Example wind vectors from MODIS

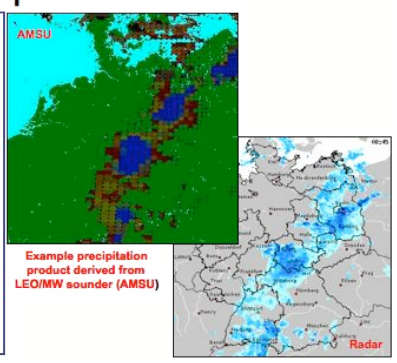
Vertical structure of convection



Precipitation

Current capabilities
- Poorly sampled
  - In-situ: Few, fixed locations
  - Radar: Regional coverage only
  - LEO satellites: Sampled 1–2x/day
  - GEO satellites: IR only Û indirect
- Poorly predicted
  - Models deficient re: convective processes

PATH capabilities
- Derived from scattering signature
  - All conditions and locations, every 15 min
  - Observe storms develop
- Continuously calibrated to GPM
- Applicable algorithms available
  - NOAA (Weng et al.)
  - UW (Bennartz et al.)
  - MIT (Staelin et al.)
  - Others under development



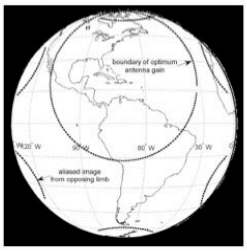
Example precipitation product derived from LEO/MW sounder (AMSU)

PATH - The Mission

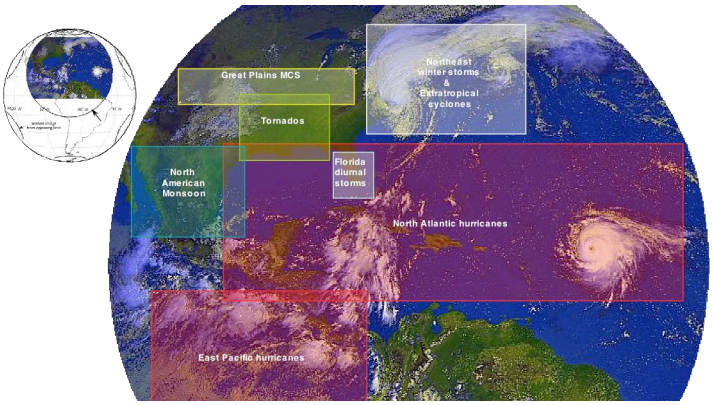
Notional mission

- **Objective: Observe US hurricanes & severe storms**
  - Primary: Atlantic hurricanes
  - Secondary: CONUS severe storms; E. Pac. hurricanes
- **ROI focused near E. Carribbean**
  - Center @ 75°W, 20°N
    - Can be pointed in other directions
  - 90+ % of visible disc is in alias-free region
    - Can be narrowed down (lower cost => risk mitigation)
  - Highest sensitivity in "circle" of radius 45°
    - Exploring antenna designs to maximize high-sensitivity region
- ***Alternative mission: "Pacific ENSO Observatory"***
- **Adequate sensitivity with array radiometer**
  - ~ 20 minutes "integration time" to reach 1/3 K for water vapor (183 GHz) in central part of ROI
    - T-band (50 GHz) is twice as sensitive/responsive
    - Exploring designs to improve these numbers
    - Exploring methods to increase temporal resolution
  - Focus is on high-value soundings in cloudy/unstable conditions
  - Synergy with scatterometer & GOES-R sensors (ABI, GLM)

"Staring" 2D array imager-sounder:
- 60,000 pixels for T-sounding
- 240,000 pixels for H_2O-sounding
- Every 15 minutes
- Covering the entire visible disc



Focus themes: Hurricanes & severe storms



Mission requirements

Mission Objectives	Measurement Requirements	Instrument Requirements	Mission Requirements
Observe and improve understanding and modeling of hurricanes, severe weather and related hydrology-cycle processes: • N. Atlantic hurricanes • CONUS severe storms • E. Pacific hurricanes • Tropical moisture transport • Oceanic and continental atmospheric processes • Diurnal cycles	**Functional** a) Soundings • T(z): 2 K/2 km • q(z): 20% / 2 km • L(z): 40% / 3 km • TPW: 10% • LWC: 20% b) SST • <0.5 K c) Precipitation • 25–50% **Temporal** • 15–30 minutes **Spatial** • T: <50 km/nadir • q: <25 km/nadir **Coverage** • Troposphere • Surface • All-weather • Continuous • ROI	**Spectral** AMSU ch. 3–8 AMSU ch. 17–20 **Radiometeric** <1K requirement <0.25 K goal **Antenna** 104/arm @ 50 GHz 192/arm @ 183 GHz ~4 λ spacing **Struct. stability** 0.5° @ center 1.5° @ periphery **Thermal** T_{op} ≈–30°C ΔT <1°C **Data bandwidth** 1 Mbps throughput	**Orbit** Geostationary, 75°W **Attitude** Pitch: 3.3°N Ctrl: 36 arcsec Stab: 1 arcsec/sec **Power & mass** Power range: 255–340 W Mass: 230 kg **Thermal** 2 m² radiator + heat pipes **Operation** Continuous **Data** Latency: <15 min Rate: 1 Mbps avg Volume: 5 GB/day **Calibration** Ground transmitter

Data products

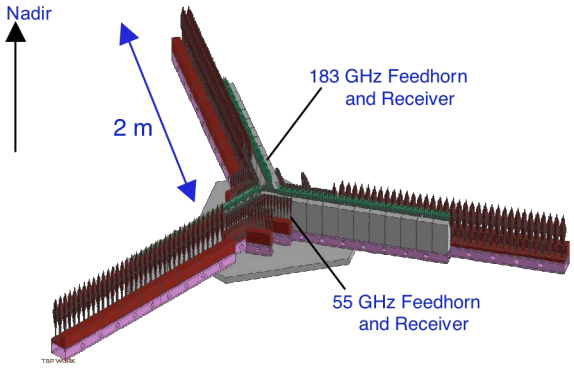
Mature products :

Parameter	Horizontal	Vertical	Temporal	Accuracy
Tb (50 GHz)	50 km	(6 channels)	3 min per ch.	< 1/3 K
Tb (183 GHz)	25 km	(4 channels)	5 min per ch.	< 1/3 K
Temperature	50 km	2 km	20 min	1.5-2 K
Water vapor	25 km	2 km	20 min	25%
Liquid water	25 km	3 km	20 min	40%
Stability index	50 km	N/A	20 min	N/A
TPW	25 km	N/A	20 min	10%
LWC	25 km	N/A	20 min	20%
SST	100 km	N/A	1 hour	< 0.5 K

Evolving experimental products:

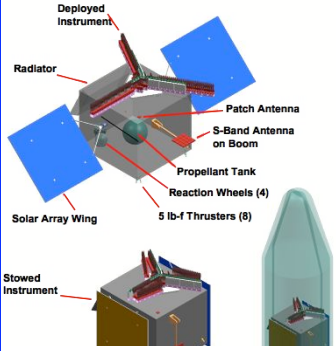
Parameter	Horizontal	Vertical	Temporal	Accuracy
Rain rate	25 km	N/A	20 min	2 mm/hr
Convect. intens.	25 km	N/A	20 min	N/A
IWC	25 km	N/A	20 min	30%
Wind vector	25 km	2 km	30 min	TBD

Payload: "Array radiometer" (GeoSTAR)

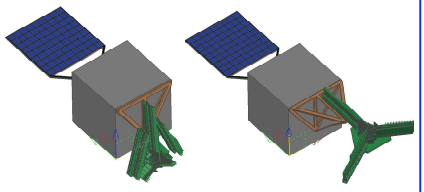


Mission options

1) Standalone mission



2) Hosted payload



Easy to integrate without interfering with other payloads

Applications

- Regional weather forecasting: all-weather observations
- Hurricane diagnostics: intensification, vertical structure
- Flood warnings: storm total precipitation
- Pollution transport: hemispheric 3-D wind fields (no gaps)
- Process studies: hydrologic cycle (vapor, liquid, ice)
- Climate studies: T/q trends, storm climatology (life cycle)

Synergy

- GPM: fill swath-time gaps
- Scatt (XOVWM): vertical continuity, surface → upper tropo.
- GOES-R: merged products with ABI, GLM & future HES
- LEO sounders (NPP/NPOESS etc.): fill swath-time gaps
- Other D-S missions: 3D-Winds, ACE (clouds), GPSRO (T/q profiles), SMAP (flooding), SWOT (river flow)

Contact: Bjorn Lambrigtsen (lambrigtsen@jpl.nasa.gov, 818-354-8932)